



BACKGROUND PAPER #6: INFRASTRUCTURE AND CRITICAL FACILITIES

INTRODUCTION

Infrastructure and critical facilities are often located on the coast within tsunami hazard areas. Because of the services these facilities provide—or the harm they can cause—to the community, their performance during natural hazard events is a community-wide concern and needs to be considered as part of a tsunami risk management effort. Managing the tsunami risk is a responsibility shared by the government and private sectors. Ownership and regulatory control over some infrastructure and critical facilities rests with special districts, state and federal government agencies, and largely autonomous investor-owned utility companies rather than local government.

This paper discusses critical facilities and infrastructure and the issues associated with locating, siting, designing, or constructing new critical facilities and infrastructure and protecting existing facilities in tsunami hazard areas.



Damage to the Washington State Highway 109 bridge over the Copalis River from the 1964 tsunami.
Credit: Army Corps of Engineers

Proposals for new critical facilities and infrastructure located in tsunami hazard areas should be considered carefully to determine whether the performance expected is acceptable once feasible design measures are implemented. Proposals for new infrastructure should be evaluated in terms of the increased risk because of “induced growth.” For example, construction of new buildings and facilities may be facilitated by the availability of new services in the hazard area. Existing infrastructure and critical facilities present vexing issues. It is difficult and expensive to improve the tsunami performance of existing facilities and infrastructure, and relocation is usually impractical, especially in the short term. However, understanding the risk to these existing facilities and anticipating the consequences of tsunami events can lead to long-term risk-reducing strategies.

KEY CONCEPTS AND FINDINGS

There are four key concepts presented in this background paper. Fundamental to all of them is the need to understand that tsunami hazard mitigation responsibilities can be very diffuse.

Depending on the community, infrastructure systems and critical facilities may be owned and managed by local and state agencies, special districts, private companies, non-profit organizations, federal departments and agencies, joint powers authorities, and others.

Concept 1: Understand and describe the nature and extent of tsunami and other hazards affecting the community

Background Paper #1 provides background information needed to conduct local tsunami risk studies. It is important to include in such studies data about infrastructure and critical facilities and to identify who is responsible for their location, design, construction, operation, and maintenance. This work would include:

- Inventorying and gathering data about infrastructure elements and critical facilities in the potential damage area; and
- Identifying the responsible organizations and including their representatives in the mitigation process.

Concept 2: To describe the performance objectives appropriate to utility and transportation systems and critical facilities

Because of the varied nature and differing importance of infrastructure systems and critical facilities, an effort must be made to “rank” their relative importance to the community and to establish performance objectives to help guide mitigation actions. This work involves several items:

- Determine how each has addressed tsunami and earthquake mitigation, plus any important site hazards such as potential landslides or soil failures;
- Establish a scale of relative importance to help focus mitigation efforts (e.g., preventing losses to the potable water system may be more important than preventing losses to the wastewater system); and
- Set acceptable outage intervals for each element (e.g., the community hospital must be minimally functional within one hour of the event, but a major street could be bypassed for two weeks).



Bore advancing through the railroad bridge at the Wailuku River
in Hilo, Hawaii, during the 1946 tsunami.
Credit: Pacific Tsunami Museum

Concept 3: Avoid locating new infrastructure elements and critical facilities in high tsunami hazard areas

While it may be difficult for many reasons, the siting of new elements and facilities in high hazard areas should be avoided whenever practical. This practice reduces community vulnerability, and by limiting services, this practice also may contribute to reduced growth in such areas. Key strategies include:

- Examine plans for such systems and facilities to see if equally efficient alternative locations, alignments, and routes can be used;
- Determine if redundancies exist or can be provided where elements and facilities must serve high-hazard areas; and
- Where it is impractical to locate them elsewhere, ensure that adequate mechanisms exist to isolate the damaged area, such as shutoff valves, detours, and others.

Concept 4: Use professional coastal and structural engineers and architects experienced in designing (or retrofitting) buildings to resist tsunami forces and resist the effects of inundation

Effective design and engineering can greatly minimize the effects of tsunamis on infrastructure and critical facilities. Communities should ensure that design professionals qualified in coastal, earthquake, and geotechnical engineering are used regularly on projects in high hazard areas. Communities should:

- Identify proposed projects that should involve specially qualified professionals;

- See that the owning organizations secure the specialized assistance as early as possible in the project planning; and
- Locate both local and distant sources of qualified assistance that can be contacted when needed.



A boat washed up over 400 feet onshore from the wharf by the 1946 tsunami in Hilo, Hawaii.
Credit: Pacific Tsunami Museum

DEFINITIONS

Table 6-1 provides examples of structures and uses typical to the following definitions:

Critical Facilities—Critical facilities are “critical” because of their occupants or the functions they contain. These facilities serve important public purposes, house large numbers of persons or special populations, or may threaten the community if their contents are released. Critical facilities include *essential service facilities*, *hazardous facilities*, and *special occupancy structures* with uses such as government activities important to sustaining a community, buildings with large numbers of occupants, or buildings with occupants who cannot evacuate the premises readily.

Essential Services Facilities—Essential services facilities include hospitals with surgery and emergency medical treatment areas, fire and police stations, garages and shelters for emergency vehicles and aircraft, structures and shelters in emergency operations and communications centers and other facilities required for emergency response, standby power generating equipment and fuel storage for essential facilities, tanks or other structures containing housing or supporting water or other fire-suppression material or equipment required for the protection of other critical facilities. Private businesses may consider some facilities as essential to their business. For example, computer facilities, communications hubs, or record storage locations may be essential to the existence of some companies.

Hazardous Facilities—Hazardous facilities include buildings and non-building structures that house or support or contain acutely and chronically toxic substances, explosive or flammable chemicals. Uncontrolled release of hazardous materials to the air or water can harm people, contaminate the environment and feed fires on land and on the water.

Hazardous facilities should safely contain their contents following a disaster. The Uniform Building Code includes requirements for the use of enhanced wind and earthquake forces in the design of hazardous facilities.

Special Occupancy Structures—Special occupancy structures include schools, colleges, large occupancy buildings, buildings and facilities with resident incapacitated patients and elder care, jails and structures, and equipment in power-generating stations and other public utility facilities. Special occupancy structures should resist hazard events without endangering the occupants. Life safety systems in these structures must be designed for forces 50 percent greater than normal.

Infrastructure—Infrastructure includes the facilities needed by the community to function and to recover after a disaster, such as transportation systems for people and goods and utility systems such as communications, natural gas, water supply, and power generation and transmission/distribution systems. The elements that compose infrastructure should be functional—or easily and rapidly repairable—following a disaster.

Waterfront-dependent Facilities—Some facilities require a location on or adjacent to the water to function as intended. They gain a significant economic advantage from a waterfront location because they receive raw materials or distribute finished products by ship, use significant quantities of seawater, or support water-related recreational and commercial uses. Ports and harbor facilities are examples. Some waterfront-dependent uses may also be essential services facilities, (e.g., a Coast Guard installation and oil spill response and cleanup facilities); some special occupancy structures, (e.g., nuclear and fossil fuel power generation stations; and some hazardous facilities, (e.g., a fuel handling and storage facility). However, most of these facilities are not dependent on a waterfront location and only need to be close—not on the water.



Tsunami inundation at the Kodiak Naval Station airstrip from the 1964 tsunami.
Credit: USGS

Table 6-1. Examples of Infrastructure and Critical Facilities

| |
|---|
| INFRASTRUCTURE |
| <p><i>Transportation Systems</i></p> <ul style="list-style-type: none"> ▪ Roads, highways, bridges, parking lots and structures, and traffic control systems ▪ Railroad-track beds, bridges, and rail and switching yards for freight and passengers ▪ Transit systems (rail, trolley, tram, and motor coach), storage and maintenance facilities, power systems and substations, control systems, bridges, tunnels, and tubes ▪ Airports and control towers ▪ Maritime ports and maritime traffic control systems, marine terminals, loading/unloading facilities, storage facilities (including tank farms), docks, and ship moorings, piers, seawalls, and bulkheads |
| <p><i>Utility Systems</i></p> <ul style="list-style-type: none"> ▪ Electrical generation, transmission, substations, and distribution systems ▪ Natural gas production, processing, storage, transmission, pump, and distribution systems ▪ Landline communication systems: switching stations, trunk lines, and data lines ▪ Cellular systems, switching stations, antenna, and towers ▪ Cable systems for television, radio, and data ▪ Satellite systems for television and data ▪ Potable water systems: wells, water supply sources, storage, pumps, and treatment and distribution systems ▪ Sewerage collection, mains, pumps, treatment facilities, and outfalls ▪ Pipelines that transport oil, fuels, and other petroleum products ▪ Storm water runoff facilities, drainage, and pipelines |
| CRITICAL FACILITIES |
| <p><i>Essential Services</i></p> <ul style="list-style-type: none"> ▪ Police stations ▪ Firehouses ▪ Hospitals with surgery, acute care, or emergency rooms ▪ Emergency operations and communications facilities and equipment ▪ Garages and shelters for emergency vehicles and aircraft ▪ Standby power-generating equipment for essential services ▪ Tanks or other structures containing water or other fire-suppression material or equipment required to protect essential, hazardous, or special occupancy facilities ▪ Permanent lifeguard stations |
| <p><i>Special Occupancy Structures</i></p> <ul style="list-style-type: none"> ▪ Schools ▪ Universities and colleges ▪ Residential treatment centers and nursing and convalescent homes ▪ Retirement communities ▪ Large-occupancy structures ▪ Power-generating stations and other utility facilities needed for continuous operations |
| <p><i>Hazardous Facilities</i></p> <ul style="list-style-type: none"> ▪ Fuel docks and storage ▪ Spent nuclear fuel storage ▪ Chemical storage facilities ▪ Rail tank cars and trucks with chemicals ▪ Munitions storage, loading docks, and harbors |

Table 6-2. Acceptable Use Matrix

| Use | Tsunami Hazard ¹ | | |
|--|-----------------------------|-------------------|-------------------|
| | High | Moderate | Low |
| Essential Facility | NO ² | NO ² | OK ³ |
| Hazardous Facility | OK ^{2,3} | OK ^{2,3} | OK ^{2,3} |
| Special Occupancy Structure | NO | NO | OK ³ |
| Maritime Infrastructure | OK ³ | OK ³ | OK ³ |
| Non-maritime Infrastructure | NO | NO | OK |
| ¹ . See Background Paper #5, “ <i>Building Design</i> ,” for a description of the tsunami hazard ² . Only if dependent on a waterfront location ³ . Only if risk reduced to the maximum extent feasible | | | |

MANAGING TSUNAMI RISK INVOLVING INFRASTRUCTURE AND CRITICAL FACILITIES

Planning Process

A planning process for new and existing infrastructure and critical facilities should involve the individuals and agencies and companies responsible for critical facilities and infrastructure. Knowledge of the nature and extent of tsunami hazard, the causes of vulnerability, and the consequences of damage are essential ingredients for risk management. These factors should be quantified to an appropriate extent and then be considered in normal decisionmaking processes such as environmental review, land use and community planning, coastal program planning, subdividing land, redevelopment of existing areas, capital outlay, and in the regulation of design and construction of structures. Studies of the hazard, vulnerability, risk, and consequences will help facility managers understand community concerns as well as the threat to their own interests.

- Define the tsunami hazard (see Background Paper #1) and describe it by intensity (expected effects) and probability of occurrence.
- Identify infrastructure and critical facilities within the tsunami hazard area and describe why their functions make tsunami resistance an important issue for the community.
- Describe what makes each facility vulnerable to damage from tsunami forces.
- Determine what appropriate performance objectives are desired (i.e., acceptable damage condition for a given tsunami intensity and probability). See Background Paper #5 for a discussion on performance objectives.
- For new infrastructure and critical facilities, determine appropriate performance objectives and whether their use is dependent on a waterfront location.

- For existing infrastructure and critical facilities, determine which mitigation options and combinations of options can reduce the risk and whether the remaining risk would be acceptable.
- Adopt policies to manage the tsunami risk and integrate them into coastal management programs, land use plans, capital outlay plans, building regulation programs, and other procedures used to control the use and safety of facilities near the ocean shoreline.
- Prepare and adopt long-term loss reduction plans with strategies that include relocating or, if possible, strengthening existing infrastructure and critical facilities against tsunami forces, and that provide redundant facilities and emergency response measures to lessen the impact of losing infrastructure and critical facilities that remain at risk.

General Principles

- Enforce zoning ordinances and building codes that address tsunamis and all other hazard conditions (seismic, fire, wind, flood inundation, erosion and scour, hazardous materials).
- Undertake community-wide studies to define the tsunami hazard by intensity, recurrence, and location.
- Essential services facilities should be operational following a hazard event. This concept already is contained in the Uniform Building Code (UBC). The UBC requires the use of enhanced seismic and winds forces for design, and enhanced structural observation during construction for essential services facilities. The UBC uses an “Importance Factor” to increase the force levels by 15 to 50 percent over those calculated for other occupancy categories to provide stronger structures.
- Prepare for the inevitable destruction of infrastructure and critical facilities located in tsunami hazard areas that cannot be newly constructed or retrofitted to withstand tsunami forces.
- When waterfront-dependent infrastructure and critical facilities cannot be newly designed or retrofitted to resist a tsunami event, they should be considered “expendable” and appropriate steps taken for evacuation, emergency response, recovery, and replacement.
- Certain types of infrastructure can affect the extent and intensity of the tsunami hazard (breakwaters, seawalls, roadway fills).
- Provide redundant facilities and infrastructure.
- Each coastal management program should provide guidance for revising or adopting measures that deal with existing and new infrastructure, critical facilities, waterfront-dependent uses, and tsunami hazards. State planning and permit jurisdiction and federal consistency requirements should incorporate these measures.

Specific Principles for Existing Infrastructure and Critical Facilities

- Strengthen or phase out existing facilities.
- Relocate portions of at-risk facilities.
- Raise existing facilities above the inundation elevation, and protect against impact forces (reinforce walls and columns) and scour.
- Construct barriers.
- Provide redundant facilities.
- Take advantage of the eventual obsolescence of existing infrastructure and critical facilities as opportunities to relocate the facility or to incorporate design standards that will allow for acceptable performance following tsunamis.
- Do not allow expansion or renovation of existing facilities in tsunami hazard areas without requiring measures to reduce the risk.
- Prepare emergency plans to cope with the emergency situation and expedite recovery.



Petroleum tank on fire due to damage from the 1964 tsunami
on Highway 101 near Crescent City, California.
Credit: Del Norte Historical Society

Principles for New Infrastructure and Critical Facilities

- Do not allow construction of new infrastructure and critical facilities in tsunami hazard areas or fail to enforce current codes and standards.
- Prohibit new critical facilities in tsunami hazard areas unless: 1) they are waterfront-dependent; 2) risk is reduced through mitigation and emergency planning measures to such an extent that the resulting facility will perform as needed; or 3) the need for the facility outweighs the consequences of loss during a tsunami (e.g., a small hospital in a remote,

tsunami-prone area may be justified because it needs to be close to the population for routine emergencies).

- Reserve sites for infrastructure and critical facilities either outside of the tsunami hazard area or in areas where the risk can be reduced through feasible measures.
- Most critical facilities need not be located in a tsunami hazard area to serve their intended purpose. Some essential facilities may need to be located in a tsunami hazard area because alternative locations will not serve the day-to-day needs of the community.
- Do not allow infrastructure improvements that will encourage construction of other facilities that cannot withstand the tsunami hazard.
- Consider the impact of new infrastructure on hazard intensity and distribution. Does it change drainage patterns, decrease exposure to inundation, or channel currents in a way that will increase the hazard?

See Appendix 6-1 for the text of provisions in the State of Oregon's statutes related to tsunami hazards that serve to illustrate acceptable use decisions.

APPENDIX 6-1:
TSUNAMI PROVISIONS IN STATE OF OREGON REVISED STATUTES

Chapter 455
1999 EDITION

455.446 Construction of certain facilities and structures in tsunami inundation zone prohibited; establishment of zone; exceptions.

- (1)(a) New essential facilities described in ORS 455.447 (1)(a)(A), (B) and (G) and new special occupancy structures described in ORS 455.447(1)(e)(B), (C) and (E) shall not be constructed in the tsunami inundation zone established under paragraph (c) of this subsection. The provisions of this paragraph apply to buildings with a capacity greater than 50 individuals for every public, private or parochial school through secondary level and child care centers.
- (b) The State Department of Geology and Mineral Industries shall establish the parameters of the area of expected tsunami inundation based on scientific evidence that may include geologic field data and tsunami modeling.
- (c) The governing board of the State Department of Geology and Mineral Industries, by rule, shall determine the tsunami inundation zone based on the parameters established by the department. The board shall adopt the zone as determined by the department under paragraph (b) of this subsection except as modified by the board under paragraph (d) of this subsection.
- (d) The board may grant exceptions to restrictions in the tsunami inundation zone established under paragraph (c) of this subsection after public hearing and a determination by the board that the applicant has demonstrated that the safety of building occupants will be ensured to the maximum reasonable extent:
 - (A) By addressing the relative risks within the zone.
 - (B) By balancing competing interests and other considerations.
 - (C) By considering mitigative construction strategies.
 - (D) By considering mitigative terrain modification.
- (e) The provisions of paragraph (a) of this subsection do not apply:
 - (A) To fire or police stations where there is a need for strategic location; and
 - (B) To public schools if there is a need for the school to be within the boundaries of a school district and this cannot otherwise be accomplished.
- (f) All materials supporting an application for an exception to the tsunami inundation zone are public records under ORS 192.005 to 192.170 and shall be retained in the library of the department for periods of time determined by its governing board.
- (g) The applicant for an exception to the tsunami inundation zone established under paragraph (c) of this subsection shall pay any costs for department review of the application and the costs, if any, of the approval process.

- (2) The definitions in ORS 455.447 apply to this section.
- (3) The provisions of this section do not apply to water-dependent and water-related facilities, including but not limited to docks, wharves, piers and marinas.
- (4) Decisions made under this section are not land use decisions under ORS 197.015 (10). [1995 c.617 s.2]

Note: 455.446 was enacted into law by the Legislative Assembly but was not added to or made a part of ORS chapter 455 or any series therein by legislative action. See Preface to Oregon Revised Statutes for further explanation.

455.447 Regulation of certain structures vulnerable to earthquakes and tsunamis. (1) As used in this section, unless the context requires otherwise:

- (a) “Essential facility,” means:
 - (A) Hospitals and other medical facilities having surgery and emergency treatment areas;
 - (B) Fire and police stations;
 - (C) Tanks or other structures containing, housing or supporting water or fire-suppression materials or equipment required for the protection of essential or hazardous facilities or special occupancy structures;
 - (D) Emergency vehicle shelters and garages;
 - (E) Structures and equipment in emergency-preparedness centers;
 - (F) Standby power generating equipment for essential facilities; and
 - (G) Structures and equipment in government communication centers and other facilities required for emergency response.
- (b) “Hazardous facility,” means structures housing, supporting or containing sufficient quantities of toxic or explosive substances to be of danger to the safety of the public if released.
- (c) “Major structure,” means a building over six stories in height with an aggregate floor area of 60,000 square feet or more, every building over 10 stories in height and parking structures as determined by Department of Consumer and Business Services rule.
- (d) “Seismic hazard,” means a geologic condition that is a potential danger to life and property which includes but is not limited to earthquake, landslide, liquefaction, tsunami inundation, fault displacement, and subsidence.
- (e) “Special occupancy structure,” means:
 - (A) Covered structures whose primary occupancy is public assembly with a capacity greater than 300 persons;
 - (B) Buildings with a capacity greater than 250 individuals for every public, private or parochial school through secondary level or child care centers;
 - (C) Buildings for colleges or adult education schools with a capacity greater than 500 persons;

- (D) Medical facilities with 50 or more resident, incapacitated patients not included in subparagraphs (A) to (C) of this paragraph;
 - (E) Jails and detention facilities; and
 - (F) All structures and occupancies with a capacity greater than 5,000 persons.
- (2) The Department of Consumer and Business Services shall consult with the Seismic Safety Policy Advisory Commission and the State Department of Geology and Mineral Industries prior to adopting rules. Thereafter, the Department of Consumer and Business Services may adopt rules as set forth in ORS 183.325 to 183.410 to amend the state building code to:
- (a) Require new building sites for essential facilities, hazardous facilities, major structures and special occupancy structures to be evaluated on a site specific basis for vulnerability to seismic geologic hazards.
 - (b) Require a program for the installation of strong motions accelerographs in or near selected major buildings.
 - (c) Provide for the review of geologic and engineering reports for seismic design of new buildings of large size, high occupancy or critical use.
 - (d) Provide for filing of noninterpretive seismic data from site evaluation in a manner accessible to the public.
- (3) For the purpose of defraying the cost of applying the regulations in subsection (2) of this section, there is hereby imposed a surcharge in the amount of one percent of the total fees collected under the structural and mechanical specialty codes for essential facilities, hazardous facilities, major structures and special occupancy structures, which fees shall be retained by the jurisdiction enforcing the particular specialty code as provided in ORS 455.150.
- (4) Developers of new essential facilities, hazardous facilities and major structures described in subsection (1)(a)(E), (b) and (c) of this section and new special occupancy structures described in subsection (1)(e)(A), (D) and (F) of this section that are located in an identified tsunami inundation zone shall consult with the State Department of Geology and Mineral Industries for assistance in determining the impact of possible tsunamis on the proposed development and for assistance in preparing methods to mitigate risk at the site of a potential tsunami. Consultation shall take place prior to submittal of design plans to the building official for final approval. [1991 c.956 s.12; 1995 c.79 s.229; 1995 c.617 s.1]
- Note: 455.447 was added to and made a part of 455.010 to 455.740 by legislative action but was not added to any smaller series therein. See Preface to Oregon Revised Statutes for further explanation.



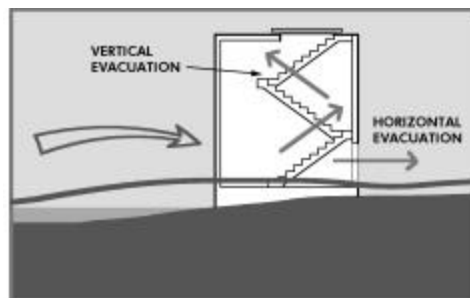
BACKGROUND PAPER #7: VERTICAL EVACUATION

INTRODUCTION

This background paper discusses the concept of vertical evacuation as it relates to the siting and design of buildings in tsunami-threatened coastal communities.

The concept of vertical evacuation originated as a hurricane emergency preparedness and response measure. Consideration of its feasibility likely began with intense development of the coastal barrier islands, often served by only one bridge. A literature search and interview results indicate that vertical evacuation may be more complicated to use in tsunami-threatened areas because of the differing hazard characteristics, such as strong groundshaking and potential ground failures, and their implications for siting, design, and construction. Other planning issues relate to managing the number of occupants, providing in-building security, compensating building owners, and addressing liability issues associated with vertical evacuation.

The primary strategy for saving lives immediately before tsunami waves arrive is to evacuate people from the hazard zone either horizontally or vertically. In some areas, vertical evacuation may be the only feasible means of evacuation for local tsunamis with short warning times. Horizontal evacuation (having people move to more distant locations when tsunamis, hurricanes or floods threaten, for example) is the most commonly used method of the two. Vertical evacuation, much less common and still in an experimental mode in some areas, helps eliminate potential congestion and travel delays by having people move to the upper stories of relatively tall, well-designed, and well-constructed buildings.



Horizontal and vertical evacuation

Whether vertical or horizontal evacuation, effective warning systems and public information, notification, and training programs are critical to the success of all evacuation measures. In addition, both methods require that reasonably close “safe buildings” be identified for rapid use, especially for locally-generated tsunamis, and that evacuation centers be designated in local emergency plans for both distant and local tsunamis. Tsunami warning systems are discussed in

more detail below. Emergency service officials are responsible for general evacuation plans and procedures.

KEY CONCEPTS

This background paper focuses on four key concepts. The information in this paper has been derived from a variety of sources discussed below, but primarily from recent research on evacuation, especially vertical evacuation, in hurricane-prone areas. Tsunami-threatened communities may find it useful to consider vertical evacuation measures, especially when neither time nor adequate routes are likely to be available for people to move inland (horizontally) away from the vulnerable area.

Concept 1: Understand Vertical Evacuation

Vertical evacuation uses existing multiple story buildings as places of refuge for evacuees. While the evacuation process is an emergency preparedness and response measure, the important mitigation consideration is that buildings must be located, designed, and constructed to withstand the expected tsunami forces—and earthquake forces if the tsunami is local—so the occupants are protected. Background Papers #1, #4, and #5 address key topics related to vertical evacuation. Properly implemented vertical evacuation measures require an understanding of:

- How tsunamis may affect your community;
- The nature of the current building stock and its ability to withstand tsunami and earthquake forces;
- Which siting, design, and construction requirements should govern new buildings that are to be designated as vertical shelters; and
- How current local emergency plans address the issues of warning, public education, and response operations.

Evacuating people can save lives and reduce injuries, but it will have little, if any, effect on reducing property and economic losses. In coastal areas where building and population densities are high, where roads, bridges, and other horizontal evacuation methods are limited, or where warning time may be insufficient, vertical evacuation may be needed as an alternative or supplement to horizontal evacuation. Land use planning, site planning, and building design issues discussed in the previous background papers determine a community's ability to rely, at least partially, on vertical evacuation to protect people.

Concept 2: Ensure Adequate Standards Apply to New Buildings

It is easier to design and construct a new building to follow prescribed standards than it is to retrofit an existing one. New buildings to be designated as vertical evacuation shelters must have sufficient structural integrity to resist expected tsunami forces and earthquake groundshaking for tsunamis originating locally. Building codes and other applicable standards should ensure the

tsunami and earthquake resistance of new buildings. These standards should go beyond the minimum life-safety requirements of most locally-adopted codes. Background Paper #5 addresses the need for adequate standards.

Communities and building owners should also seek additional technical information and secure the assistance of qualified professionals in the fields of coastal, geotechnical, and structural engineering.

Concept 3: Inventory Existing Buildings

The building stock for vertical evacuation varies greatly across communities. Thus, it is critical that a community inventory and assess buildings that could serve as vertical evacuation shelters. This may be difficult because important information about existing buildings, such as drawings and calculations, may not be available. Professional engineers play a key role in evaluating the capacity of structures to resist expected forces and motions, and their reports often lead to rehabilitation and retrofit work designed to strengthen the buildings.

Depending on the nature of the existing building stock, some structures may be capable of sheltering people for a limited amount of time. In general, they should be at least two stories tall, with the first being left open to inundation. Some may have to be strengthened to serve this purpose. Designating existing buildings as vertical evacuation shelters includes the following:

- Conducting an engineering survey of existing buildings that could be candidate shelters;
- Working with the owners and others involved to have such buildings retrofitted, if needed, and designated as shelters; and
- Posting or otherwise notifying people which buildings have been designated to serve as shelters following tsunami warnings or strong groundshaking due to local earthquakes.

Concept 4: Ensure Emergency Plans and Information Programs Address Evacuation

Vertical evacuation, while dependent on structures for its success, primarily is an emergency preparedness and response measure. It is important, therefore, that those community officials responsible for planning and managing emergency programs and operations have lead responsibility for vertical evacuation planning. In addition, it is extremely important to involve building owners and others in the process of establishing a vertical evacuation program.

Evacuating people from threatened areas may have to be done on very short notice. Local emergency plans and preparedness programs should contain procedures for receiving and disseminating warnings, facilitating the movement of people, and regularly providing residents and especially seasonal visitors with warning and evacuation information. This includes:

- Reviewing the nature and density of regular and seasonal occupants in the potential inundation areas;

- Ensuring informational, local warning, and public announcement systems are regularly tested and capable of informing occupants;
- Addressing and resolving any legal or regulatory issues associated with implementing vertical evacuation procedures; and
- Including appropriate evacuation measures in local emergency operations plans, including procedures for early post-tsunami/local earthquake evacuee care and damage evaluations.



Tsunami evacuation route sign in Crescent City, California.
Credit: FEMA

DIFFERING HAZARD CHARACTERISTICS

While creating similar types of damage, tsunamis and hurricanes are different in many respects. Because hurricanes are generated at some distance, they can be tracked with some precision, and timely warnings can be issued, even if the hurricanes change their course. Advance warning allows the public to take precautionary actions, such as evacuating the area to more distant locations. The wind-driven water (storm surge) that creates coastal flooding also is predictable, moves relatively slowly, only batters shoreline structures, and inundates only the lower levels of buildings, such as basements and ground floors.

Tsunamis, on the other hand, can be generated at great distances or locally, and each type may be accompanied by multiple waves. Tsunami waves can move at great speeds, can be, but are not always, very high (50 feet or more), and can carry extensive amounts of debris that act as battering rams, such as trees, boulders, building wreckage, cars, shipping containers, and boats.

Where they exist, warning systems can notify people of distant tsunamis, providing them with up to several hours to take protective actions. These warnings can provide sufficient time to shut down critical activities and to evacuate low lying areas for higher or more distant locations. On the other hand, locally-generated tsunamis provide almost no warning time (5-30 minutes), and

they may be accompanied by strong earthquake groundshaking, landslides, and other on-shore effects. Problems may be exacerbated by building damage, utility system failures, and transportation system outages, especially in areas subject to ground failure, such as liquefaction, lateral spreading, and slumping.

Thus, the siting and design considerations for hurricanes and both local and distant tsunamis are substantially different. Tsunami mitigation guidelines have to address the peculiarities associated especially with locally-generated tsunamis accompanied by other earthquake effects.

TSUNAMI WARNING PROGRAMS

The following is a description of tsunami warning programs. This topic is not directly related to the building issues involved in vertical evacuation, but provides helpful background information.

As part of an international cooperative effort to save lives and protect property, the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service operates two tsunami warning centers. The West Coast and Alaska Tsunami Warning Center (WCATWC) in Palmer, Alaska, serves as the regional tsunami warning center for Alaska, British Columbia, Washington, Oregon, and California.



Tsunami hazard zone logo

The Pacific Tsunami Warning Center (PTWC) in Ewa Beach, Hawaii, serves as the regional tsunami warning center for Hawaii and as a national/international warning center for tsunamis that pose a Pacific-wide threat. This international warning effort became a formal arrangement in 1965 when PTWC assumed the international warning responsibilities of the Pacific Tsunami Warning System (PTWS). The PTWS is composed of 26 international member states that are organized as the International Coordination Group for the Tsunami Warning System in the Pacific.

The objective of the tsunami warning centers is to detect, locate, and determine the magnitude of potentially tsunamigenic earthquakes. Earthquake information is provided by seismic stations. If the location and magnitude of an earthquake meet the known criteria for generation of a tsunami, a tsunami warning is issued to warn of an imminent tsunami hazard. The warning includes predicted tsunami arrival times at selected coastal communities within the geographic area defined by the maximum distance the tsunami could travel in a few hours. A tsunami watch with

additional predicted tsunami arrival times is issued for a geographic area defined by the distance the tsunami could travel in a subsequent time period.

If a significant tsunami is detected by sea-level monitoring instrumentation, the tsunami warning is extended to the entire Pacific Basin. Sea-level (or tidal) information is provided by NOAA's National Ocean Service, PTWC, WCATWC, university monitoring networks, and other participating nations of the PTWS.

Tsunami watch, warning, and information bulletins are disseminated to appropriate emergency officials and the general public by a variety of communication methods:

- Tsunami watch, warning, and information bulletins issued by PTWC and WCATWC are disseminated to local, state, national, and international users as well as the media. These users, in turn, disseminate the tsunami information to the public, generally over commercial radio and television channels.
- The NOAA Weather Radio System, based on a large number of VHF transmitter sites, provides direct broadcast of tsunami information to the public.
- The U.S. Coast Guard also broadcasts urgent marine warnings and related tsunami information to coastal users equipped with medium frequency (MF) and very-high-frequency (VHF) marine radios.
- Local authorities and emergency managers are responsible for formulating and executing evacuation plans for areas under a tsunami warning. The public should stay tuned to the local media for evacuation orders should a tsunami warning be issued. And, the public should not return to low-lying areas until the tsunami threat has passed and the local authorities announce the "all clear."

Earthquakes with preliminary magnitudes of 7.0 are used to trigger warning systems because that is a threshold magnitude where tsunami generation is more likely to occur, with sufficient displacement and fault area. Of course, smaller earthquakes may generate tsunamis, or more likely, trigger submarine landslides that generate tsunamis. These would probably be missed by the warning center, and the tsunami would more likely be a local event.

GENERAL CONSIDERATIONS

It appears from recent research that residents of densely populated metropolitan areas are more supportive of vertical evacuation compared to those people in the smaller urban (or largely rural) areas. A study of the feasibility of vertical evacuation noted that “Smaller urban areas generally do not have the large populations and the accompanying traffic problems found in metropolitan areas. Therefore, vertical evacuation incorporated into horizontal evacuation is not a pressing issue.” (Ruch, et al., xi)

Further information from this and two other related studies noted below provide additional insights into the issues associated with the potential use of vertical evacuation in tsunami hazard areas:

- (1) The evacuation feasibility study notes that “In some coastal areas, the time needed to achieve successful inland evacuation already exceeds the maximum possible advance warning time. As traditional “horizontal” evacuation plans become less feasible, “vertical” evacuation into properly designed high-rise buildings capable of riding out hurricane stresses is becoming an appealing alternative. The six authors of this anthology considered the behavioral and logistical feasibility of vertical evacuation, ramifications of public tort liability in evacuation situations, legal authority and liability concerns in Texas and Florida, political problems that emerge with vertical evacuation policies, and the structural viability of large buildings to survive hurricane phenomena. Some of the findings reported include: 1) government intervention or regulation will be required to achieve vertical refuge; 2) the majority of respondents to a survey indicated that they would use vertical shelter; and 3) Florida, and to a lesser extent Texas, has started the process to implement vertical evacuation as a public policy alternative.” (Ruch, et al.)
- (2) An article on the experience of two states notes that “With growing coastal populations expected to compound problems associated with hurricane evacuation planning, some authorities are paying more attention to the possibility of vertical sheltering. This article discusses the pros and cons of vertical sheltering, presents the findings of a case study that compares hurricane awareness and risk perception among residents of Texas and Florida, and considers the viability of implementing vertical sheltering policies in both states. Three major conclusions are reached: 1) a tangible hurricane safety situation must be identified as a precondition to discussing policies involving vertical shelter; 2) a fortuitous “window of opportunity” does not necessarily lead to the adoption of a hurricane safety policy; and 3) the conditions of acceptance of a vertical shelter policy depends on the presence of an advocate, communication among key participants, linkage to other issues, and the presence of an acceptable solution.” (Berke)
- (3) An evaluation of hurricane shelters describes “a procedure for evaluating the storm resistance of buildings in low-lying coastal areas that have been, or may

be, designated as hurricane shelters. Developed during a study of hurricane shelters in the Florida Keys, the report reviews building plans, examines potential problems due to site location, and analyzes the resistance of shelters to wind, water, and storm-driven debris. The method used to analyze resistance incorporates design data pertaining to footings, columns, soil bearing capacity, floors, roofs, exterior and interior bearing walls, interior shelter potential, and mechanical/structural projections such as canopies or air conditioning units. Two detailed case studies illustrate this analytical method. The authors suggest that vertical evacuation should be used only as a last resort. The designation of vertical evacuation shelters may encourage people not to physically leave an area when extreme hurricane conditions are forecast.” (Spangler, et al.)

Finally, the evacuation feasibility study states that “The technical feasibility of vertical evacuation has its basis in the historically superior performance of engineered structures in wind hazards. In the United States, no multistory structure designed by professional architects and engineers and subjected to wind forces primarily generated by hurricane or tornado has been observed to collapse... Vertical evacuation may therefore be considered structurally feasible in a particular situation if...[its] use leads to a saving of lives. For a given scenario, the level of risk at which the use of vertical evacuation begins to result in a net saving of lives may be defined as the level of risk at which a building may be considered safe.” (Ruch, et al., xv-xvi)

OCCUPANCY, SECURITY, AND LIABILITY

It is relatively easy to move owners and tenants higher in buildings to avoid the flooding of lower floors. This can be done via building safety plans, and all occupants can be notified about this procedure and provided with instructions about what to do. The principal questions to be resolved are: How long will they be there, and what kinds of support will the people need for the duration of their stay, such as food, water, power, and sanitary services?

Vertical evacuation becomes far more complicated if the building is designated or assumed to be a public shelter. Many newer buildings have sophisticated security systems effectively limiting access to the public. Even if a building is publicly accessible, capacity issues can be a problem. For example, it may be a recipe for a riot if 1,000 people are allowed to use the building as a shelter and 5,000 appear in response to an approaching tsunami.

In addition to those issues to resolve above, others relate to supporting strangers, such as providing sufficient space, anticipating the acceptance or resistance by the tenants of outsiders, ensuring the security of tenants’ space and property, and paying the extra costs to care for the non-tenants. A particular concern may be the number of elderly people who may have problems climbing stairs (Ruch, et al., xi).

There could be liability problems in both public and non-public shelters. One problem could be determining the presumed standard of care under these conditions. Another could be determining who is responsible for ensuring that it is provided. A third liability issue could be determining

who, if anyone, is at fault if the building is damaged or destroyed resulting in fatalities and injuries, possibly creating a mass casualty incident. The following excerpts from the evacuation feasibility study offers insights into liability issues:

- *Is governmental intervention or regulation required to achieve vertical refuge?* ...There are currently no market incentives inducing private owners to assume the additional costs of strengthening, outfitting, or retrofitting their buildings for vertical refuge, must less the potential additional liability inherent in such refuge.
- *If state or local governments decided not to provide for vertical refuge, would they be held liable if people were injured or killed because they were unable to evacuate a vulnerable coastal area?* No...Absent a constitutional or statutory requirement, courts will not substitute their judgment for that of the legislature, under the doctrine of separation of powers. [Where there is no mandate] no state or local government would be held liable for failure to enact such legislation.
- *Can regulations require owners to retrofit existing buildings or design new buildings for vertical refuge?* Yes. Legislatures have the power to enact both prospective and retrospective building regulations in all jurisdictions, subject to a number of constitutional safeguards.
- *If states or local governments enacted regulations governing vertical refuge in privately owned buildings, could they be liable for money damages 1) if they failed to enforce the regulations? Or 2) if they were negligent in the course of their enforcement?* There are no clear-cut answers to these questions [because] the determination of governmental liability varies from state to state according to constitutional, legislative, or judicial determinations of sovereign immunity.

However, if any governmental unit should choose to implement VR (Vertical Refuge), legal duties of care would arise (under the doctrine of sovereign immunity). Depending on each state's torts claims act, the state would be immune from liability for injury or death arising from certain executive branch actions implementing established policy while other implementing actions would subject the state to liability if it failed to meet the applicable duty of care. . . .Under Texas common law, the duty owed would depend on whether those entrants are classified as invitees, licensees, or trespassers. . . .In Florida, persons volunteering buildings for use as emergency shelters without compensation can not [sic] be held liable for injury to or death of shelterees, unless they act with gross negligence or willful and wanton misconduct...Under Florida common law, the duty owed would depend on whether the entrant is an invited or uninvited visitor.

If action is brought within the statute of limitations, architects, engineers, and builders of buildings used as VR shelters would be highly vulnerable to liability if their errors caused injury to those taking VR (Ruch, et al., xi-xiv).

VERTICAL EVACUATION MEASURES

The use of a building for vertical evacuation implies that the building is expected to be damaged only to the extent that it is not a threat to life and that it could continue to serve as a temporary safe shelter. Life safety is a governmental objective, and for normal structures, it is provided by the adoption and effective enforcement of building codes, which commonly allow for substantial damage as long as few casualties result from it.

Moreover, building codes usually address only new buildings or substantial modifications to existing buildings. Very few, or only special codes, laws, or ordinances, address the complexities associated with rehabilitating or retrofitting existing buildings to meet life safety threats posed by expected hazards.

Local governments should consider vertical evacuation in the design of new buildings or the rehabilitation of existing buildings to support emergency evacuation activities, especially those taken in response to local tsunamis. In addition to applying the information spatially from the hazard study to locate candidate “safe buildings,” this will require that all of them be evaluated to determine their individual survivability from both direct tsunami impacts and those associated with local earthquakes, such as groundshaking, liquefaction, and other potential ground failures. Other background papers suggest appropriate siting, design, and construction measures to help ensure the survivability of existing and future buildings.

Near-shore coastal tsunami barriers, breakwaters, and sea walls may be ways of reducing the impacts of tsunamis. By helping to absorb the impacts of tsunamis, some buildings closer to the shore could serve as shelters and would be more immediately accessible. This would require both the proper design (including height) of the barriers and the buildings.

While many of the general principles governing liability are common, the specifics in each state can be quite different. It is, therefore, important that the liability implications of evacuation be examined by representatives of each state.

It is equally important that local emergency managers address the subject of evacuation in their emergency operations plans, including providing adequate warning, communications, public education, and training programs.

Listed below are specific vertical evacuation plan strategies to reduce tsunami exposure for people.

Identify Specific Buildings to Serve as Vertical Shelters

Some existing buildings can serve as vertical shelters and newer ones can be located, designed, and constructed with that use in mind. Local building officials and consulting engineers can help inventory the community’s stock of candidate buildings, evaluate the buildings’ tsunami- and earthquake-resistant capabilities, and establish criteria and standards for rehabilitation or new construction that meet the expected hazard forces so the buildings will be able to serve as shelters.

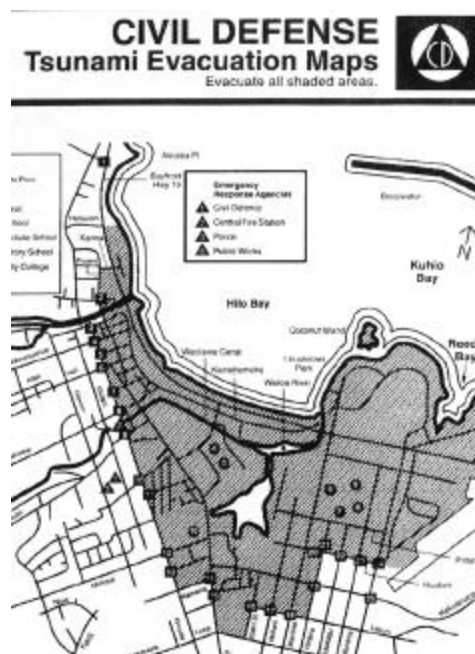
Factors to be considered in determining building suitability include size, number of stories, access, contents, and available services. Only those buildings that are judged able to withstand the potential tsunami and earthquake forces and that meet other occupancy criteria should be designated as shelters. For example, if expected tsunami wave heights will not exceed one story (about ten feet), then open-floor designs can be used to allow the waves to pass through with minimal impact on the building. Further information about evaluating the tsunami resistance of existing buildings is discussed under Background Paper #5.

Work Out Agreements and Procedures with Building Owners

To a large extent, vertical evacuation shelters will be designated in privately owned buildings. For a program to be effective, therefore, appropriate agreements should be negotiated with the owners, and the owners or their representatives should be involved in the creation and maintenance of the program. While they will vary among communities and states, issues related to notification, standards of care, compensation, duration of occupancy, security, and liability will be important to the owners.

Ensure Procedures Exist to Receive and Disseminate Warnings

It is very important that tsunami-vulnerable communities ensure that procedures and systems exist for notification by official warnings so appropriate actions can be taken, sometimes many hours in advance for distant tsunamis. Local tsunamis pose special problems because insufficient time might preclude official warnings. Some communities are advising and training their residents and visitors to evacuate immediately whenever earthquake shaking is felt. If no tsunami warning is issued, people can return after a short time.



Tsunami evacuation route map from the civil defense section of the Hilo, Hawaii, telephone book.

Implement Effective Information and Education Programs

Communities can use brochures, single-page instructions, periodic warning system tests, electronic and print media information, signs, and emergency response exercises to maintain awareness and instill effective response behavior. Some of this information will be directed towards special institutions, such as schools, hospitals, and convalescent-care facilities, and non-English speaking community members. Because of seasonal tourism in many coastal communities, some provide information especially for tourists. Depending on the community's needs, it is important that information and education efforts be routine, comprehensive, and directed toward special facilities and populations.

Maintain the Program Over the Long Term

Tsunamis are rare events, but their impacts on coastal communities can be devastating. It is a challenge to maintain emergency preparedness programs and procedures when the threat is perceived as remote. It is, therefore, important that vertical evacuation measures not only be integrated into community response plans, but that they be reviewed and revised regularly. Since cooperation is essential, these reviews should include building owners and others involved in the program. Periodic simulations are a valuable learning exercise, and regular informational and instructional materials should be provided to those occupying potential tsunami damage areas.

APPENDICES

Appendices:
Glossary

GLOSSARY

Amplitude:

The tsunami's rise above or drop below the ambient water level as read on a tide gauge.

Bore:

Traveling wave with an abrupt vertical front or wall of water. Under certain conditions, the leading edge of a tsunami wave may form a bore as it approaches and runs onshore. A bore may also be formed when a tsunami wave enters a river channel, and may travel upstream penetrating to a greater distance inland than the general inundation.

Harbor Resonance:

The continued reflection and interference of waves from the edge of a harbor or narrow bay. This interference can cause amplification of the wave heights and extend the duration of wave activity from a tsunami.

Horizontal Inundation Distance:

The distance that a tsunami wave penetrates onto the shore. Measured horizontally from the mean sea level position of the water's edge, it is usually measured as the maximum distance for a particular segment of the coast.

Inundation:

The depth, relative to a stated reference level, to which a particular location is covered by water.

Inundation Area:

An area that is flooded with water.

Inundation Line (limit):

The inland limit of wetting, measured horizontally from the edge of the coast, defined by mean sea level.

Local/Regional Tsunami:

Source of the tsunami is within 1000 km of the area of interest. Local or near-field tsunami has a very short travel time (30 minutes or less), mid-field or regional tsunami waves have times on the order of 30 minutes to 2 hours. Note: "local" tsunami is sometimes used to refer to a tsunami of landslide origin.

Period:

The length of time between two successive peaks or troughs. May vary due to complex interference of waves. Tsunami periods generally range from 5 to 60 minutes.

Run-up:

Maximum height of the water onshore observed above a reference sea level. Usually measured at the horizontal inundation limit.

Seiche:

An oscillating wave in a partially or fully enclosed body of water. May be initiated by long period seismic waves, wind and water waves, or a tsunami.

Tidal Wave:

Common term for tsunami used in older literature, historical descriptions, and popular accounts. Tides, caused by the gravitational attractions of the sun and moon, may increase or decrease the impact of a tsunami, but have nothing to do with their generation or propagation. However, most tsunamis (initially) give the appearance of a fast-rising or fast-ebbing tide as they approach shore, and only rarely appear as a near-vertical wall of water.

Travel Time:

Time (usually measured in hours and tenths of hours) that it took the tsunami to travel from the source to a particular location.

Tsunami:

A Japanese term derived from the characters “tsu” meaning harbor and “nami” meaning wave. Now generally accepted by the international scientific community to describe a series of traveling waves in water produced by the displacement of the sea floor associated with submarine earthquakes, volcanic eruptions, or landslides.

RESOURCES FOR LOCAL GOVERNMENT OFFICIALS AND THE PUBLIC

Compiled by Lee Walkling, Library Information Specialist, Washington Department of Natural Resources, Division of Geology and Earth Resources

BOOKS

American Institute of Professional Geologists, 1993. *The Citizens' Guide to Geologic Hazards—A Guide to Understanding Geologic Hazards, Including Asbestos, Radon, Swelling Soils, Earthquakes, Volcanoes, Landslides, Subsidence, Floods, and Coastal Hazards*. Arvada, CO: American Institute of Professional Geologists. (Good overview and easy-to-understand explanations)

Myles, Douglas, 1985. *The Great Waves*. New York: McGraw-Hill Book Company. (For the general public)

Mileti, Dennis S., 1999. *Disasters by Design—A Reassessment of Natural Hazards in the United States*. Washington, D.C.: John Henry Press. (Preparedness and mitigation)

Atwater, Brian F.; Marco V. Cisternas; Joanne Bourgeois; Walter C. Dudley; James W. Hendley, II; Peter H. Stauffer, compilers, 1999. *Surviving a Tsunami—Lessons from Chile, Hawaii, and Japan*. U.S. Geological Survey Circular 1187.

U.S. Federal Emergency Management Agency, 1998. *The Project Impact Hazard Mitigation Guidebook for Northwest Communities—Alaska, Idaho, Oregon, Washington*. Washington, D.C.: U.S. Federal Emergency Management Agency. (Good list of additional resources and websites and books in the appendix.)

U.S. Federal Emergency Management Agency, 1993. *Are You Ready? Your Guide to Disaster Preparedness*. Washington, D.C.: U.S. Federal Emergency Management Agency.

U.S. Federal Emergency Management Agency, 1998. *Property Acquisition Handbook for Local Communities*. 3 vol. poster (FEMA 317). Washington D.C.: U.S. Federal Emergency Management Agency. (For more information: <http://www.fema.gov/mit/handbook/>)

U.S. Federal Emergency Management Agency, 2000. *Coastal Construction Manual—Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Residential Buildings in Coastal Areas*. 3rd. ed., 3 vol. (FEMA 55) Washington, D.C.: U.S. Federal Emergency Management Agency. (For more information: <http://www.fema.gov/MIT/bpat/bpn0600e.htm>)

PERIODICALS

Natural Hazards Observer (print and online versions)

(<http://www.colorado.edu/IBS/hazards/o/o.html>)

The bi-monthly newsletter of the Natural Hazards Center. It covers current disaster issues; new international, national, and local disaster management, mitigation, and education programs; hazards research; political and policy developments; new information sources; upcoming conferences; and recent publications.

TsuInfo Alert Newsletter

The bi-monthly newsletter of the National Tsunami Hazards Mitigation Program is distributed to approximately 250 emergency managers of the five Pacific coastal states. Back issues are online: <http://www.wa.gov/dnr/htdocs/ger/tsuinfo/index.html>

WEBSITES

<http://www.geophys.washington.edu/tsunami/intro.html>

University of Washington Geophysics Program - many links to other tsunami sites

<http://www.fema.gov/library/tsunamif.htm>

FEMA tsunami fact sheet and links

<http://www.pmel.noaa.gov/tsunami/>

NOAA/PMEL Web site, with links to inundation mapping, modeling, events, forecasting and the National Tsunami Hazards Mitigation Program sites

<http://www.pmel.noaa.gov/tsunami-hazard/links.html>

Important links to major tsunami sites

<http://www.redcross.org/disaster/safety/guide/tsunami.html>

Red Cross tsunami site, with overview, discussion of warning systems, and good preparedness information

<http://www.geocities.com/CapeCanaveral/Lab/1029/>

The Tsunami Page of Dr. George P.C. (Pararas-Carayannis)

Just about everything you'd need to know about tsunamis!

<http://www.fema.gov/mit/handbook>

Property Acquisition Handbook for Local Communities (FEMA 317)

VIDEOS

Forum: Earthquakes and Tsunamis (2 hrs.)

CVTV-23, Vancouver, WA (January 24, 2000)

Two lectures: Brian Atwater describes the detective work and sources of information about the January 1700 Cascadia earthquake and tsunami; Walter C. Dudley talks about Hawaiian tsunamis and the development of warning systems.

Tsunami: Killer Wave, Born of Fire (10 min.)

NOAA/PMEL

Features tsunami destruction and fires on Okushiri Island, Japan; good graphics, explanations, and safety information. Narrated by Dr. Eddie Bernard (with Japanese subtitles).

Waves of Destruction (60 min.)

WNET Video Distribution

An episode of the "Savage Earth" series. Tsunamis around the Pacific Rim.

Disasters Are Preventable (22 min.)

USAID

Ways to reduce losses from various kinds of disasters through preparedness and prevention.

Tsunami: Surviving the Killer Waves (13 min.)

DOGAMI

Two versions, one with breaks inserted for discussion time.

Raging Planet; Tidal Wave (50 min.)

Produced for the Discovery Channel in 1997, this video shows a Japanese city that builds walls against tsunamis, talks with scientists about tsunami prediction, and has incredible survival stories.

CONTACTS: STATE LAND USE PLANNING AND COASTAL PLANNING OFFICES

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home page: <http://www.dced.state.ak.us/mra/Home.htm>

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Alaska Coastal Program homepage: <http://www.alaskacoast.state.ak.us/>

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home page: <http://www.ceres.ca.gov/coastalcomm/web/>

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Land Use Program and Hawaii Coastal Zone Management Program

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Honolulu, Hawaii 96804
(808) 587-2809
fax: (808) 587-2899
home page: <http://www.hawaii.gov/dbedt/op.html>

Oregon

Department of Land Conservation and Development

Richard Benner, Director (e-mail: Dick.Benner@State.OR.US)
635 Capitol Street NE, Suite 150
Salem, OR 97301
(503) 373-0050
fax: (503) 378-6033
home page: <http://www.lcd.state.or.us/>

Oregon Coastal Management Program

Eldon Hout, Coastal Program Manager
Department of Land Conservation and Development
(503) 731-4065, Ext. 28
e-mail: eldon.hout@state.or.us

Washington

Growth Management Program

Shane Hope, Managing Director (e-mail: shaneh@cted.wa.gov)
Department of Community, Trade and Economic Development (CTED)
906 Columbia St. S.W.
P.O. Box 48300, Olympia, WA 98504-8300
(360) 753-2222
fax: (360) 753-2950
home page: <http://www.cted.wa.gov/info/lgd/growth/index.html>

Shorelands & Environmental Assistance Program

Gordon White, Manager (e-mail: gwhi461@ecy.wa.gov)
Department of Ecology
PO Box 47600, Olympia, WA 98504-7600
(360) 407-6000
home page: <http://www.wa.gov/ecology/sea/shorelan.html>

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